Climate Variability, Hydrology, and Flooding

Introduction to NASA Remote Sensing Missions,
Earth System Models, and Data Access Tools
Relevant for Monitoring Climate Variability and Flooding

Objective

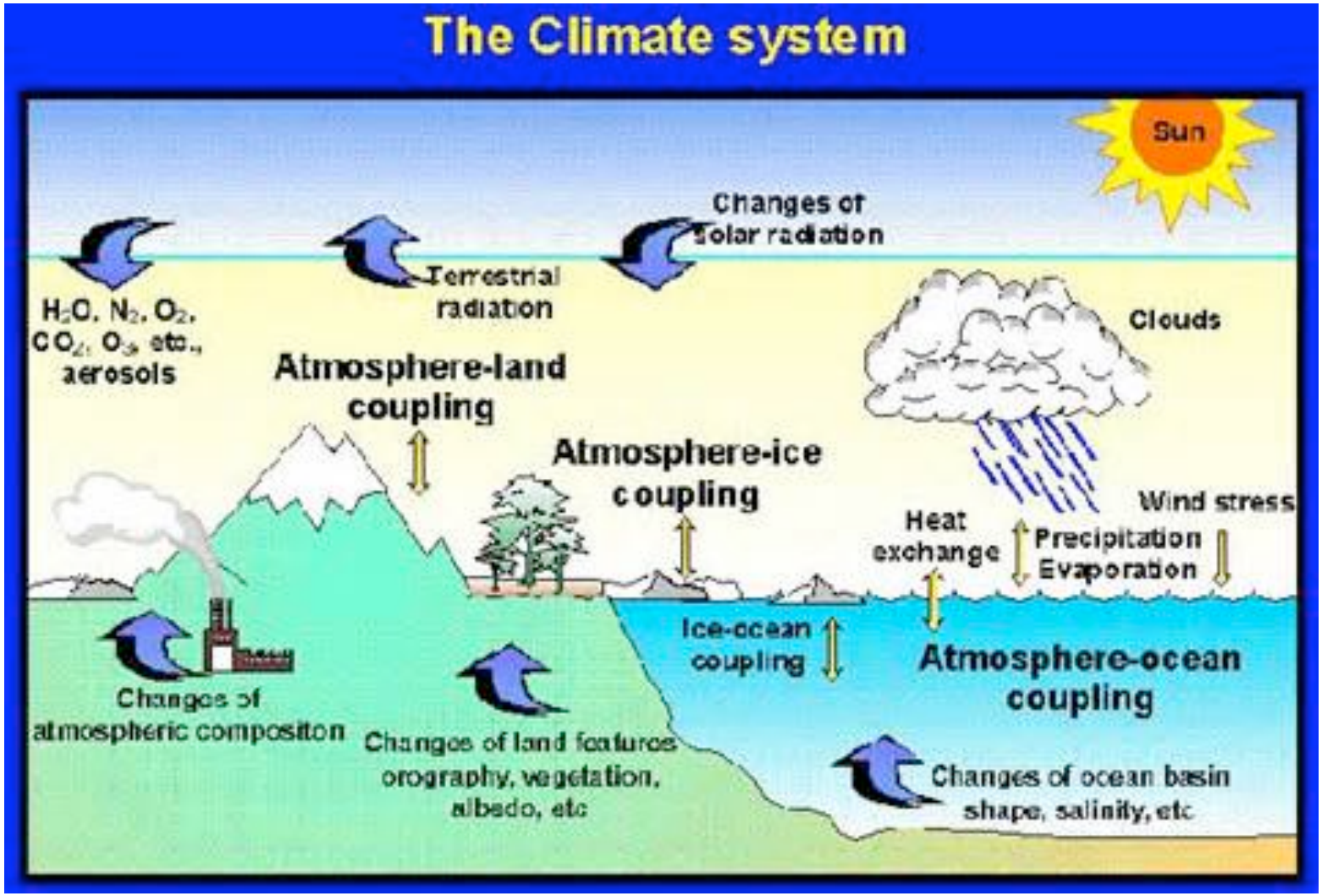
To introduce NASA satellite missions and Earth Science (ES) Models, and Data Access Tools used in this Training on Climate, Hydrology, and Flood (CHF) Monitoring

Outline

- Geophysical Quantities used for Climate, Hydrology, and Flood (CHF) Monitoring
- NASA Satellite Missions for CHF Monitoring
- NASA Earth Systems Models for CHF Monitoring
- Data Search, Access, Analysis, and Visualization Tools - Focus Giovanni

Geophysical Quantities Used for Climate, Hydrology, and Flood (CHF) Monitoring

The Climate and Hydrologic System



Geophysical Quantities and Units used for CHF Monitoring

❑ Solar and Terrestrial Radiation	(Watts/m^2)
❑ Surface Temperature	(Celsius or Kelvin)
❑ Rain	(mm/unit time or kg/m^2/s)
❑ Soil Moisture	(m^3/m^3 or g/m^2)
❑ Snow/Ice	(% area cover, mm/hour)
❑ Terrain	(vertical meter)
❑ Ground Water	(m^3 or km^3)
❑ Land Cover	(Type of Land, e.g. water, forest, grass)
❑ Evapotranspiration	(mm/s or kg/m^2/s)
❑ Run off/Streamflow	(mm/s or kg/m^2/s)
❑ Winds	(m/s)
❑ Specific Humidity	(g/kg)
❑ Clouds	(% area cover)

NASA Earth Science Provides All the Geophysical Quantities for CHF Monitoring

- Solar and Terrestrial Radiation
- Rain
- Surface Temperature
- Soil Moisture
- Snow/Ice
- Clouds, Humidity
- Terrain
- Ground Water
- Land Cover
- Evapotranspiration
- Run off/Streamflow
- Winds

All these quantities are available from NASA satellite observations as well as from atmosphere-land models
Quantities in green are derived from satellite observations
Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

NASA Earth Science Provides All the Geophysical Quantities for CHF Monitoring

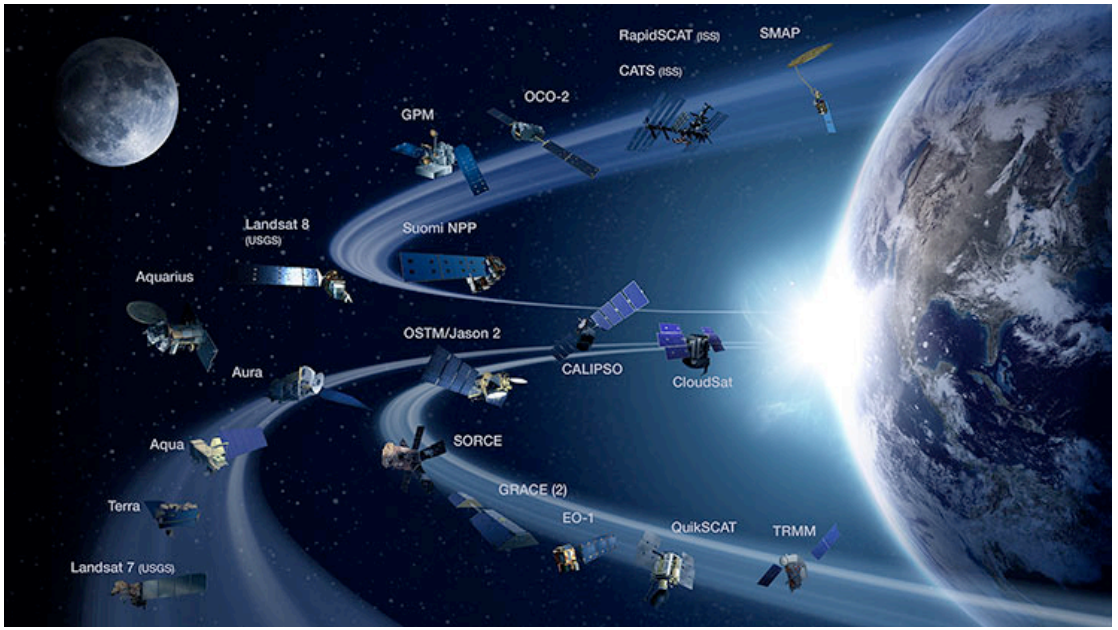
- Solar and Terrestrial Radiation
- Rain
- Surface Temperature
- Soil Moisture
- Snow/Ice
- Clouds, Humidity
- Terrain
- Ground Water
- Land Cover
- Evapotranspiration
- Run off/Streamflow
- Winds

This training will focus on these parameters

All these quantities are available from NASA satellite observations as well as from atmosphere-land models
Quantities in green are derived from satellite observations
Quantities in red are from land and atmosphere-land models in which satellite observations are assimilated

NASA Satellite Missions for CHF

NASA Earth Observing Satellites for CHF



TRMM: Tropical Rainfall Measuring Mission
GRACE: Gravity Recovery and Climate Experiment
GPM: Global Precipitation Measurements
SMAP: Soil Moisture Active Passive

Landsat (07/1972-present)

TRMM (11/1997-4/2015)

GPM (2/27/2014-present)

Terra (12/1999-present)

Aqua (5/2002-present)

SMAP (1/31/2015-present)

GRACE (3/2002-present)

NASA Earth Observing Satellites for CHF Monitoring

- Each satellite carries one or more sensors/instruments with specific spectral channels to observe specific geophysical quantities
- Sensors most used for the CHF monitoring will be described throughout this training

Landsat (07/1972-present)

TRMM (11/1997-04/2015)

GPM (2/27/2014-present)

Terra (12/1999-present)

Aqua (5/2002-present)

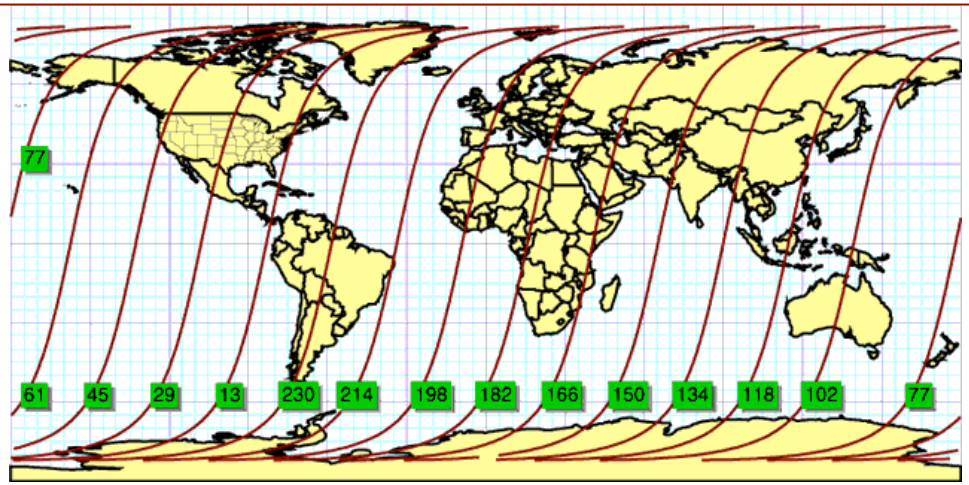
SMAP (1/31/2015-present)

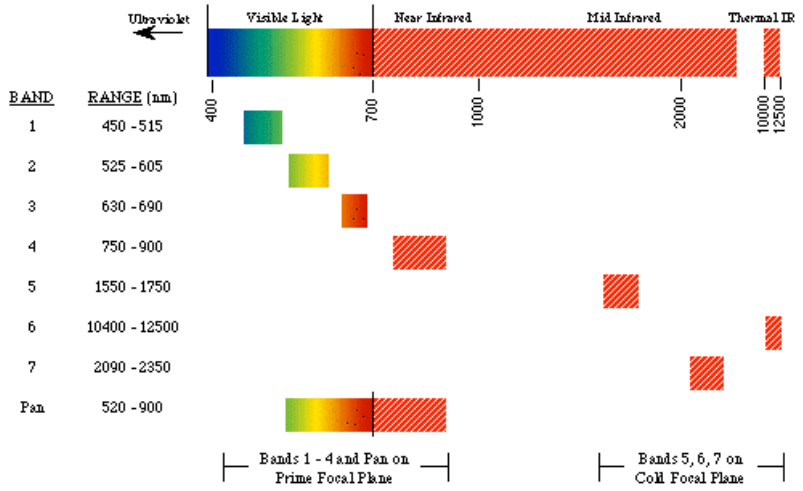
GRACE (3/2002-present)

Landsat (07/1972 – Present)

http://landsat.gsfc.nasa.gov/

Continuous mission with multiple satellites, Landsat-1 launched in July 23, 1972





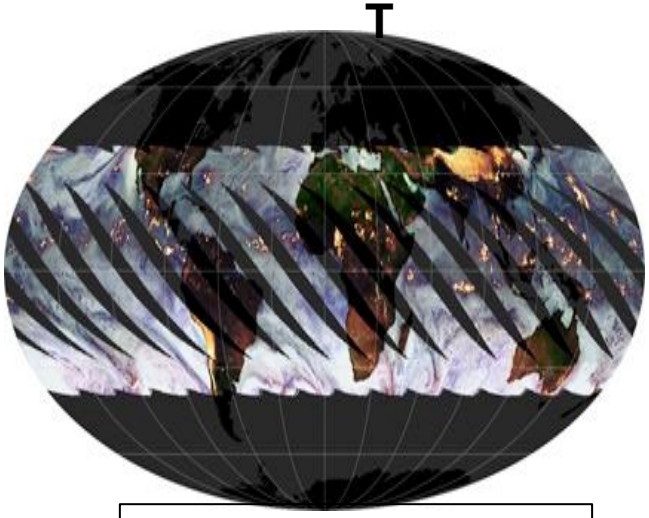
- Near-polar orbit, 10 am equator-crossing time
- Global coverage
- July 1972- Present, 16-day revisit time
- Sensors: *MSS,TM, ETM+,OLI, TIRS*

Quantities:
Land Cover

TRMM (11/1997 – 4/2015)

http://trmm.gsfc.nasa.gov

TRMM stopped collecting data in April 2015



Quantities:
Surface Rainfall
Rainfall Profiles
Latent Heating

- **A non-polar, low inclination orbit**
  Revisit time ~11-12 hours, but time of the observation changes daily
- There are 16 TRMM orbits a day **covering global tropics between 35° S to 35°N latitudes**
- Sensors

  *Precipitation Radar (**PR**)**
  *TRMM Microwave Imager (**TMI**)*
  *Visible and Infrared Scanner (**VIRS**)*

Important Note:
TRMM mission was terminated in April 2015 but near-real time TRMM-calibrated rainfall from other satellites are available until GPM data become available in near-real time

TRMM data from 1997-2014 are widely used for weather, climate, and hydrology applications and will be used in this training

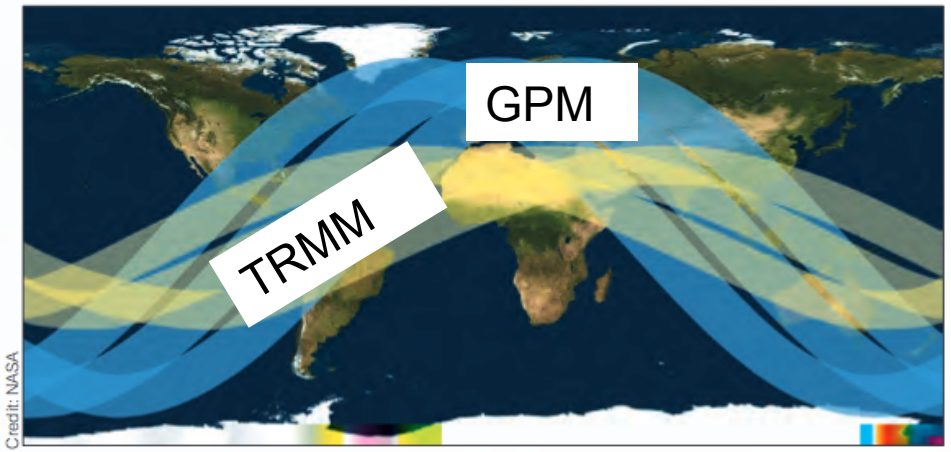
GPM (2/2014 – Present)

http://pmm.nasa.gov/GPM

GPM near-real time data will be available in 2016

- Non-polar, low inclination orbit with 16 orbits per day
- **GPM observes global region between 65°S to 65°N latitudes**
- Sensors:

  *Dual frequency Precipitation Radar (**DPR**)*
  *GPM Microwave Imager (**GMI**)*

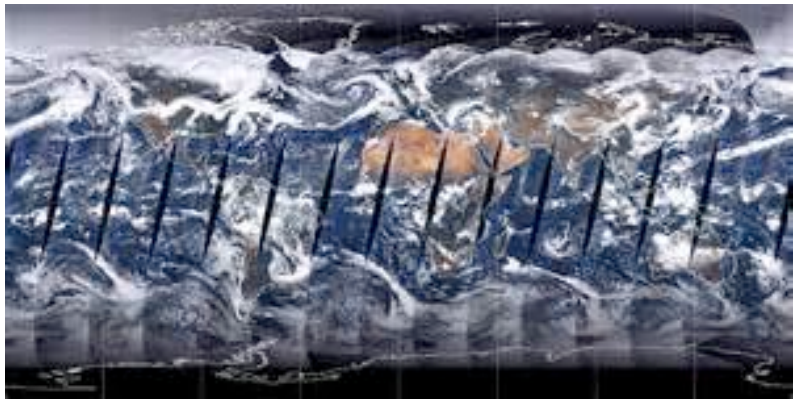


the area covered by three TRMM orbits [yellow] versus orbits of the GPM Core Observatory [blue]

Quantities:
Surface Precipitation (Rain and Snow)
Precipitation Profiles

Terra (12/1999 – Present)

http://terra.nasa.gov



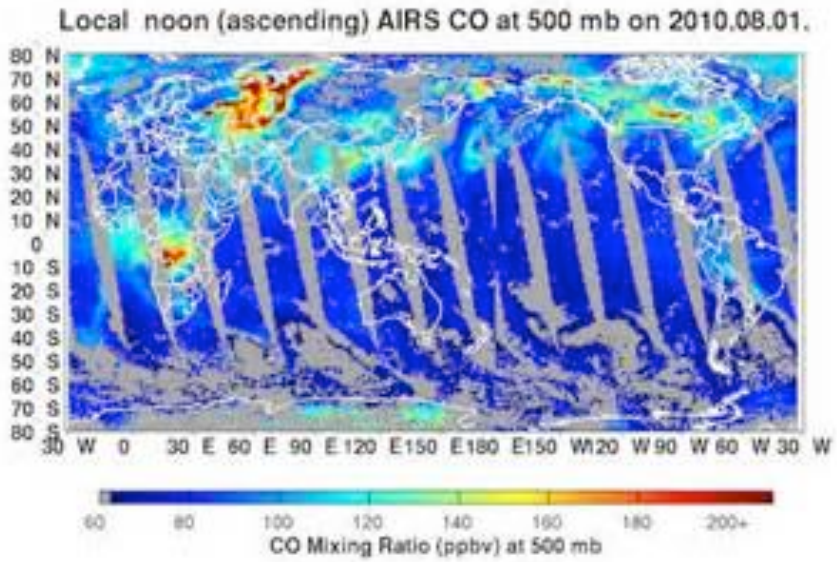
Quantities:
Land Cover
Snow Cover
Clouds
Water VApor
Radiative Fluxes
Aerosol Information
Digital Elevation

- Polar, Sun-Synchronous Orbit, Global Coverage
- Twice-daily Observations **10:30 AM/ PM** Descending Orbits
- Sensors:
  - *Moderate Resolution Imaging Spectroradiometer* ***(MODIS)***
  - *Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER)*
  - *Clouds and Earth's Radiant Energy System (CERES)*
  - *Multi-angle Imaging Spectroradiometer (MISR)*
  - *Measurements of Pollution in the Troposphere (MOPITT)*

Aqua (5/2002 – Present)

http://aqua.nasa.gov

- Polar, Sun-Synchronous Orbit, Global Coverage
- Twice-daily Observations **1:30 AM/ PM** Descending Orbits
- Sensors:
  - *Moderate Resolution Imaging Spectroradiometer* (***MODIS***)
  - *Atmospheric Infrared Sounder (AIRS)*
  - *Advanced Microwave Sounding Unit (AMSU-A)*
  - *Advanced Microwave Scanning Radiometer for EOS (AMSR-E)*
  - *Clouds and the Earth's Radiant Energy System (CERES)*

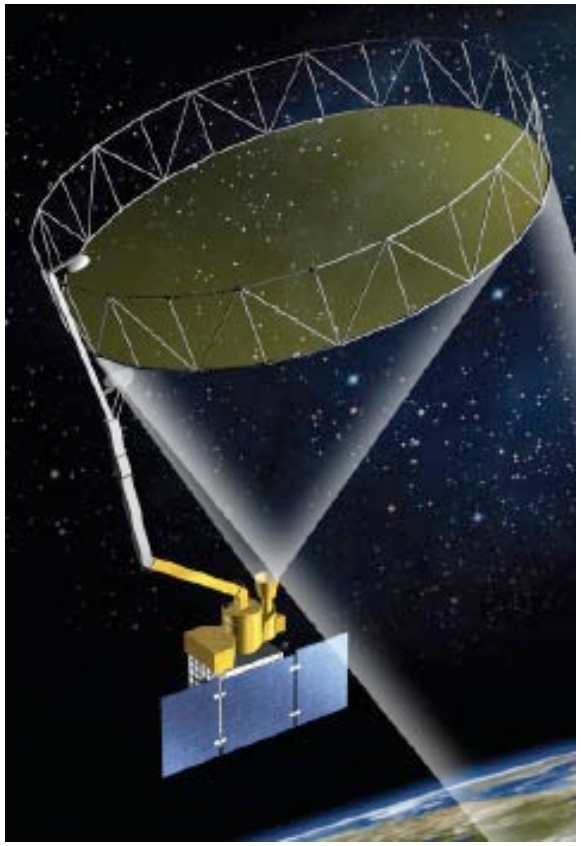


Quantities:

Land Cover
Snow Cover
Clouds
Temperature, Humidity
CO_2, CO, CH_4, O_3
Radiative Fluxes
Aerosol Information

SMAP (1/2015 – Present)

http://smap.jpl.nasa.gov

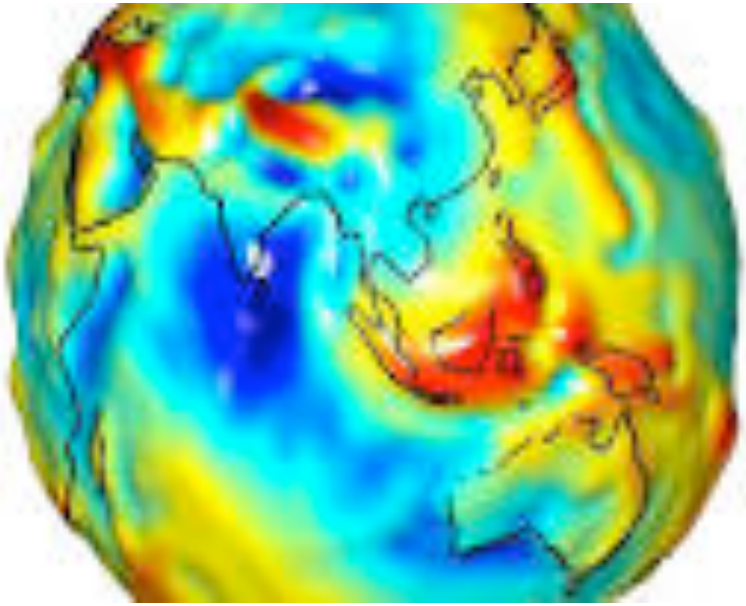


- Polar, Sun-Synchronous Orbit, Global Coverage
- Twice-daily Observations **6:00 AM/ PM** Equator Crossing
- Sensors:
  Microwave Radiometer
  Microwave Radar

Quantities:
Soil Moisture
Freeze-Thaw State

GRACE (3/2002 – Present)

http://www.jpl.nasa.gov/missions/details.php?id=5882



- Polar, Sun-Synchronous Orbit, Global Coverage
- 250 gravity profiles per day
- Sensors:
  - *Microwave K-band ranging instrument*
  - *Accelerometers*
  - *Global Positioning System Receivers*

Quantity:
Terrestrial Water

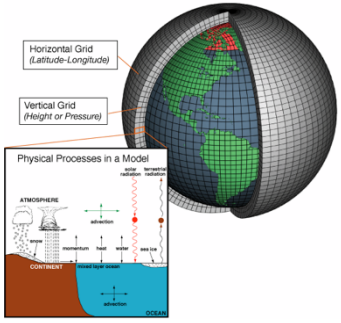
NASA Earth System Models for CHF Monitoring

Models Provide Value-added Information

Remote Sensing + Surface Observations + Numerical Models

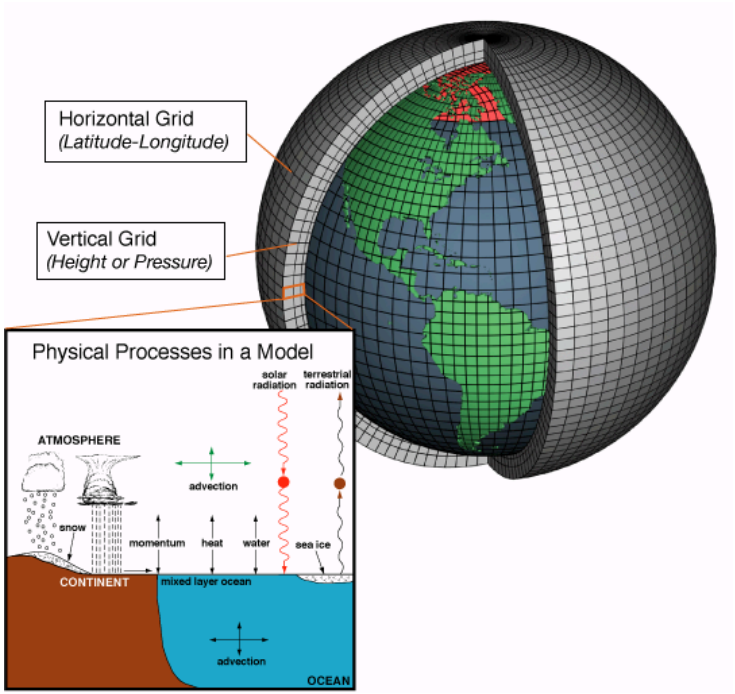
Satellite Data

Surface Measurements and In-Situ Data



Numerical Models

Modeling of the atmosphere-Land-Ocean Systems



- Models use the Laws of physics in terms of mathematical equations to represent the atmosphere, ocean, and land systems
- Applied on horizontal and vertical grids by using numerical methods
- **Models use observations to represent the atmosphere-ocean-land system** at a given time to deduce how the system will evolve over space/time
- Models use physical/statistical/empirical techniques to represent environmental processes

NASA Models for CHF Monitoring

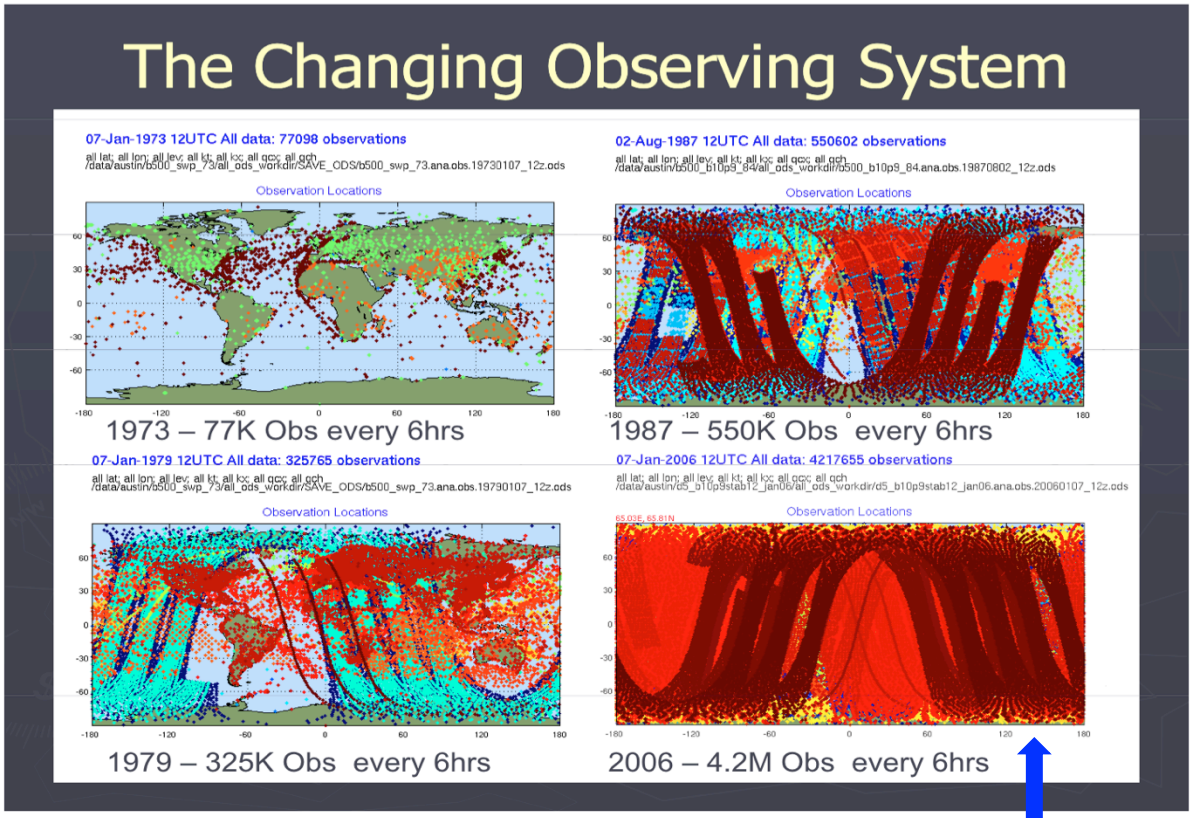
(Atmosphere-Ocean-Land Models)

- GEOS-5 : The Goddard Earth Observing System Version 5
- MERRA: Modern Era Retrospective-analysis for Research and Application
- GLDAS : Global Land Data Assimilation System
- NLDAS : North American Land Data Assimilation System

MERRA

http://gmao.gsfc.nasa.gov/merra/

Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model [**1979-present**]

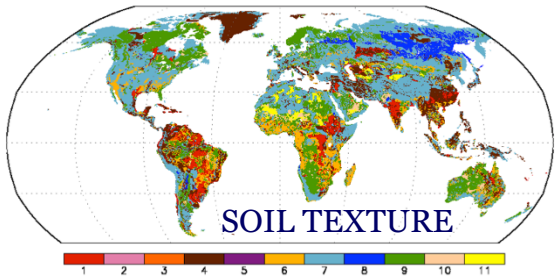


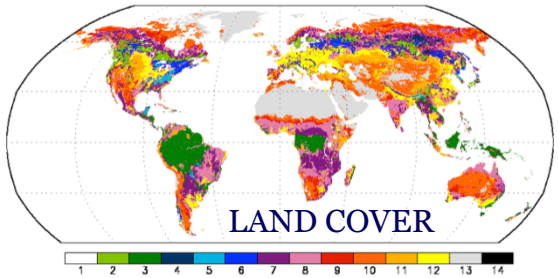
Current satellite coverage assimilated in MERRA

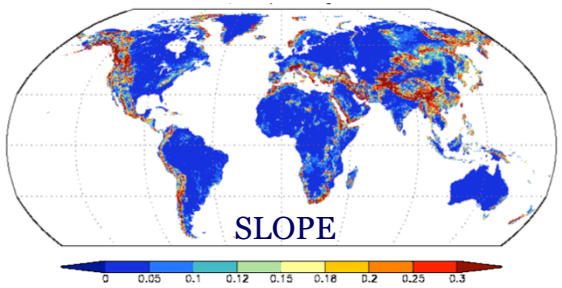
Global Land Data Assimilation System (GLDAS)

GOAL: Integrate ground and satellite observations within sophisticated numerical models to produce physically consistent, high resolution fields of land surface states (e.g., snow) and fluxes (e.g., evaporation)

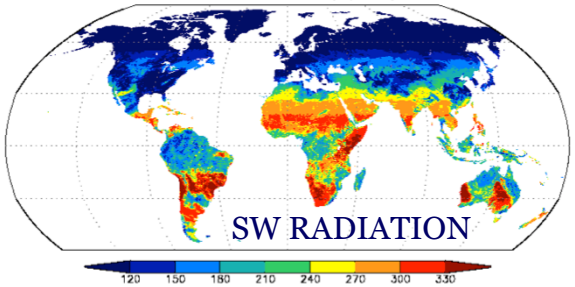
Parameter Inputs

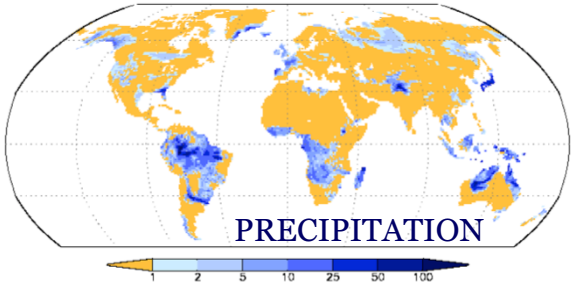






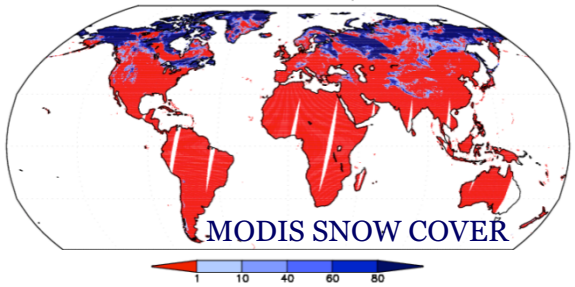
Satellite Based Forcing





AVAILABILITY: Output from 1979-present simulations of Noah (1/4°; 1°), CLM (1°), and Mosaic (1°), and VIC (1°), are available at http://disc.gsfc.nasa.gov /hydrology/index.shtml

Assimilated Observations



USES: Weather and climate forecast initialization studies, water resources applications, hydrometeorological investigations

Integrated Output

Soil Moisture
Evapotranspiration
Runoff
Snow Water Equivalent

Courtesy Matt Rodell,

NASA-GSFC

http://ldas.gsfc.nasa.gov/

Quantities Available from Models for CHF Monitoring

Models	Quantities
MERRA	3-dimensional Winds, Temperature, Humidity, Clouds, Rain Rate ,Snow Mass, Snow Cover, Snow Depth, Surface Snowfall Rate, Evapotranspiration
GLDAS	Multi-layer Soil Moisture Evapotranspiration, Rainfall, Snowfall, Snow Melt, Snow-Water Equivalent, Surface and Sub-surface Runoff

This Training will Focus on the Following Geophysical Quantities for CHF Monitoring

❑ Surface Temperature	(Aqua/AIRS)
❑ Rain	(TRMM, GPM)
❑ Soil Moisture	(GLDAS, SMAP)
❑ Snow Cover	(Terra and Aqua MODIS)
❑ Terrain	(Shuttle Radar Topography Mission)
❑ Land Cover, Inundation	(Terra and Aqua MODIS)
❑ Run Off/Streamflow	(TRMM)
❑ Winds	(MERRA)

Data Search, Access, Analysis, and Visualization Tools

There are Multiple Web-based Tools for CHF Data Search, Analysis, and Download Options

Mirador For Most CHF Data Access

Giovanni-4: **Geospatial Interactive Online Visualization ANd aNalysis Infrastructure**

Selected Data Access

PPS-STORM: **Precipitation Processing Systems - Science Team On-Line Request Module (STORM)**

Precipitation Data Access

NSIDC: **National Snow and Ice Data Center and JPL Snow Server**

Snow and Soil Moisture Data Access

Reverb-ECHO Selected Data Access

Overview of the Data Tools

Tools	**Data Formats**	Analysis and/or Visualization	Data Download
Mirador http://mirador.gsfc.nasa.gov	HDF5, OPenDAP (can be converted to ASCII, Binary, NetCDF)	N/A	Batch Download
Giovanni http://giovanni.gsfc.nasa.gov/giovanni/	NetCDF, GeoTIFF, PNG	**Visualization:** Map, Time Series, Scatter Plot Histogram **Analysis:** Time-averaged Maps, Time Series, Scatter Plot, Map Correlations, Vertical Profiles, Time-averaged Differences	Download by Select and Click on Data Files
PPS/STORM https://storm.pps.eosdis.nasa.gov/storm	HDF5, PNG	Map Visualization, Interactive Latitude/Longitude Point Data Value Display	FTP

Overview of the Data Tools

Tools	**Data Formats**	Analysis and/or Visualization	Data Download
NSIDC http://nsidc.org/	HDF5, GeoTIFF,, Binary (Data Product Dependent)	Data Search And Images	FTP Download Via Reverb
Reverb-ECHO http://reverb.echo.nasa.gov/reverb	HDF, Image	Map Visualization	Batch Download Possible

Overview of Giovanni

Geospatial Interactive Online Visualization ANd aNalysis Infrastructure

http://giovanni.gsfc.nasa.gov/giovanni/

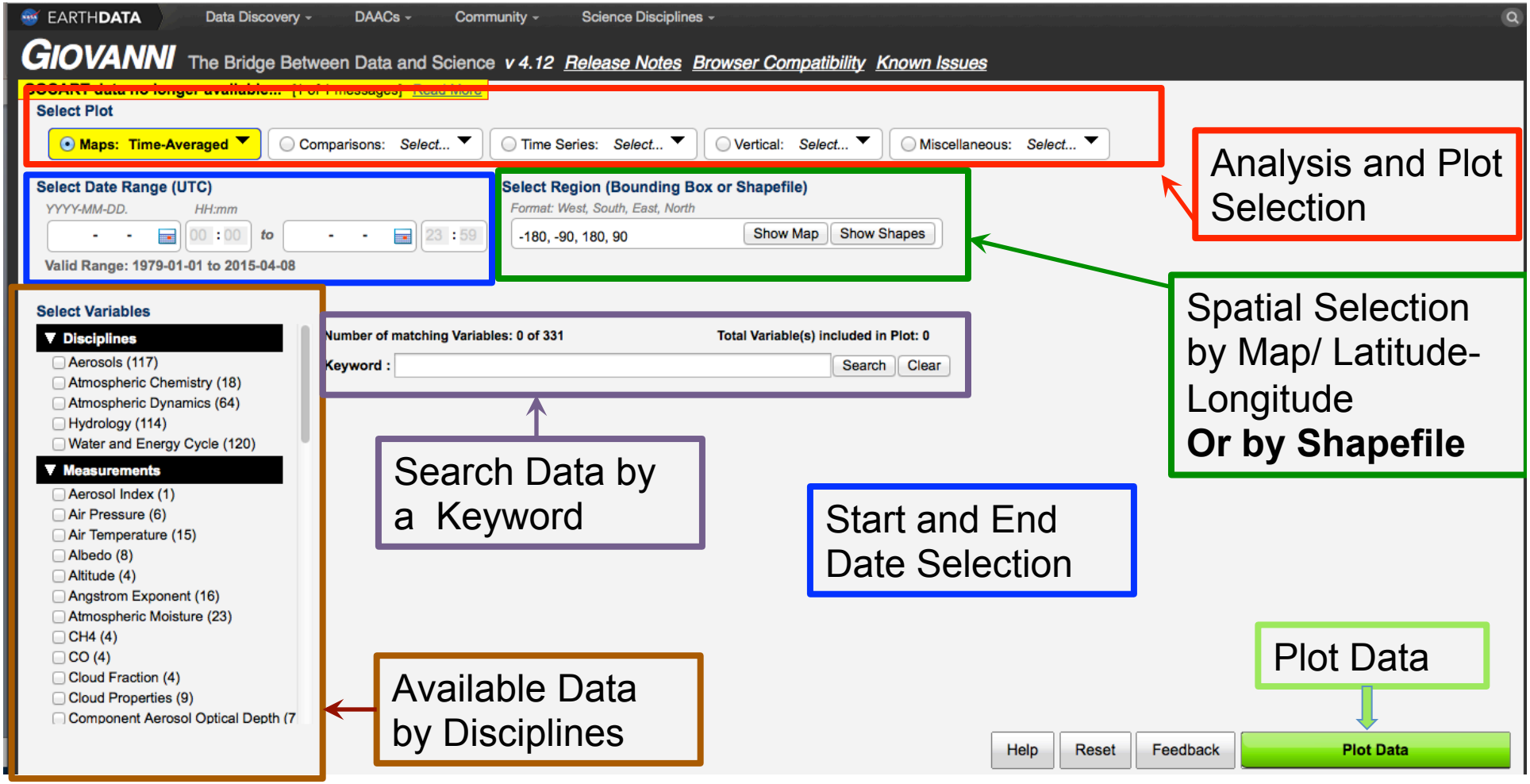
What is Giovanni?

http://disc.sci.gsfc.nasa.gov/giovanni/overview/what-is-giovanni

- Giovanni is an acronym for the **G**eospatial Interactive Online Visualization ANd aNalysis Infrastructure
- Giovanni is a Web-based application developed by the Goddard Earth Sciences Data and Information Services Center (GES DISC)
- Giovanni provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data

Giovanni

http://giovanni.gsfc.nasa.gov/giovanni/



Giovanni

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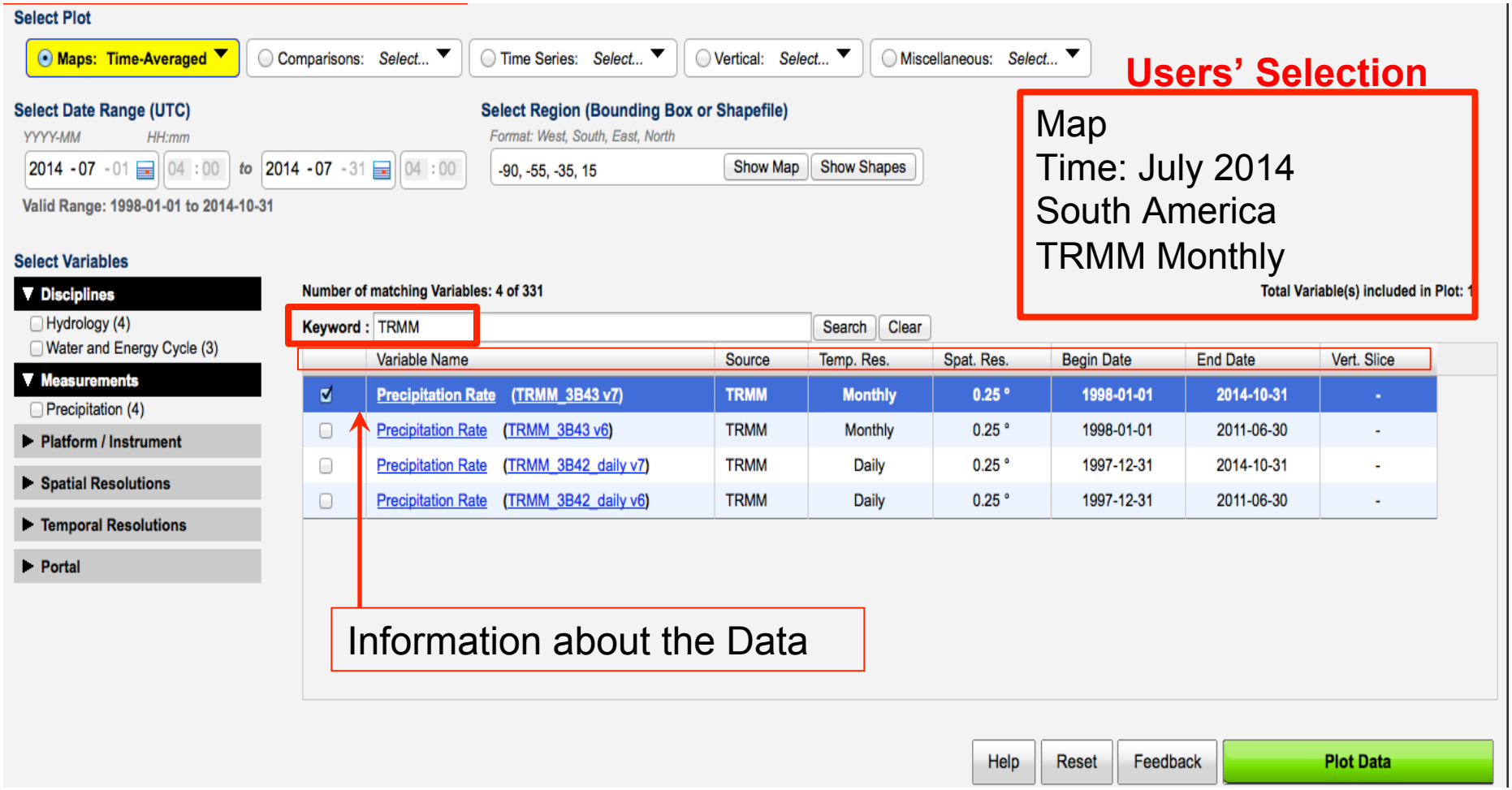

Giovanni

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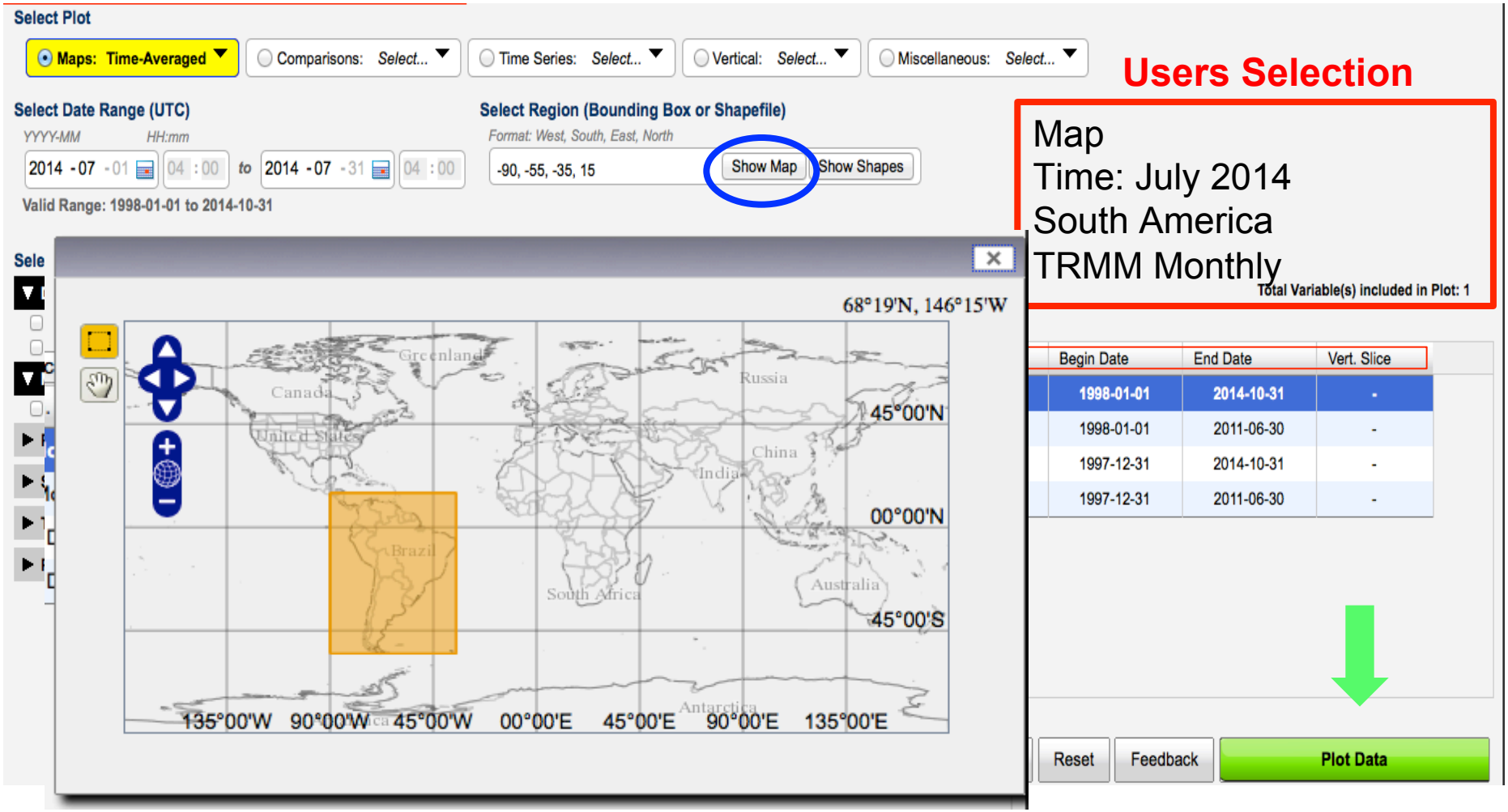
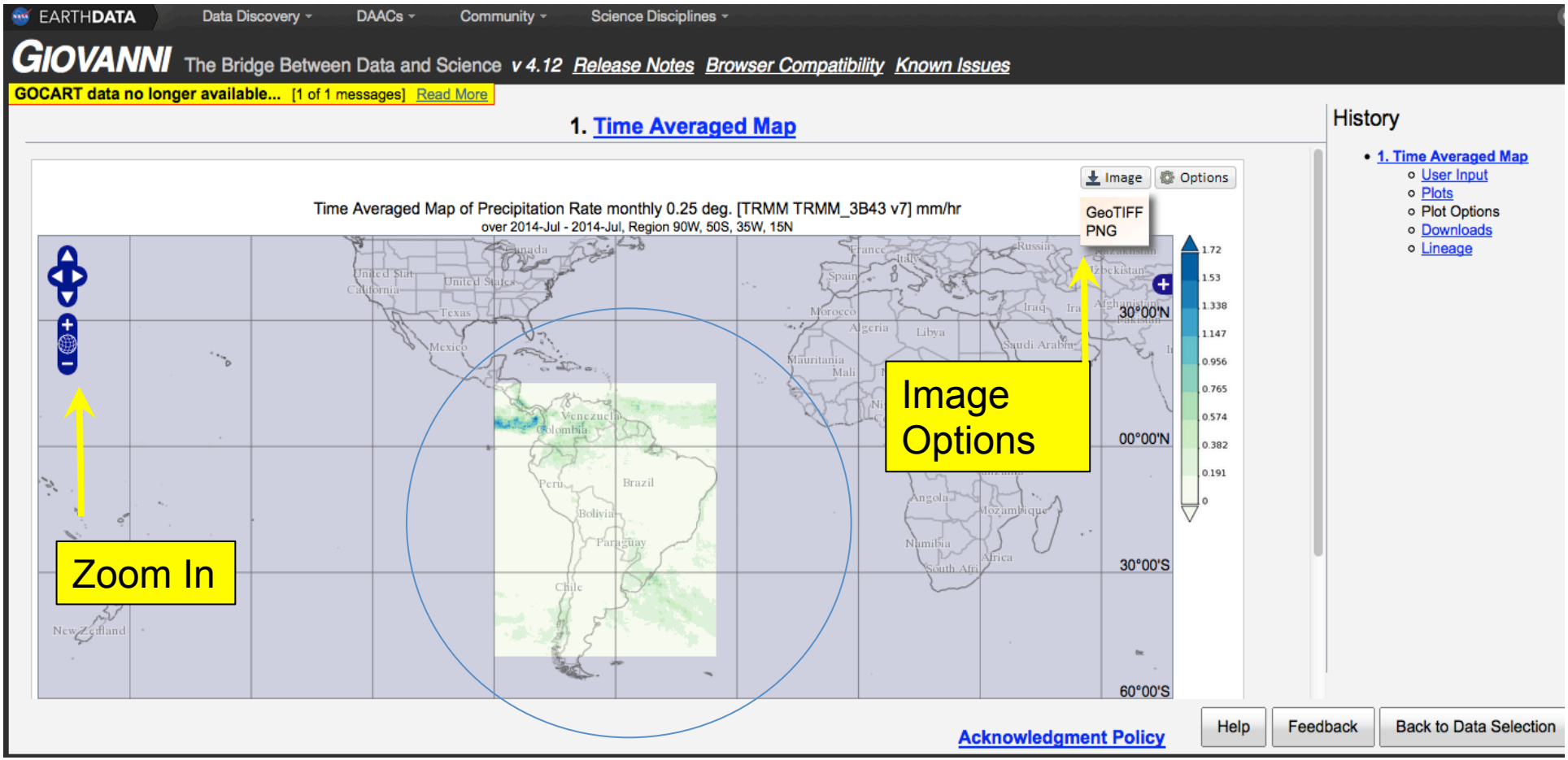


User-Selected Map from Giovanni



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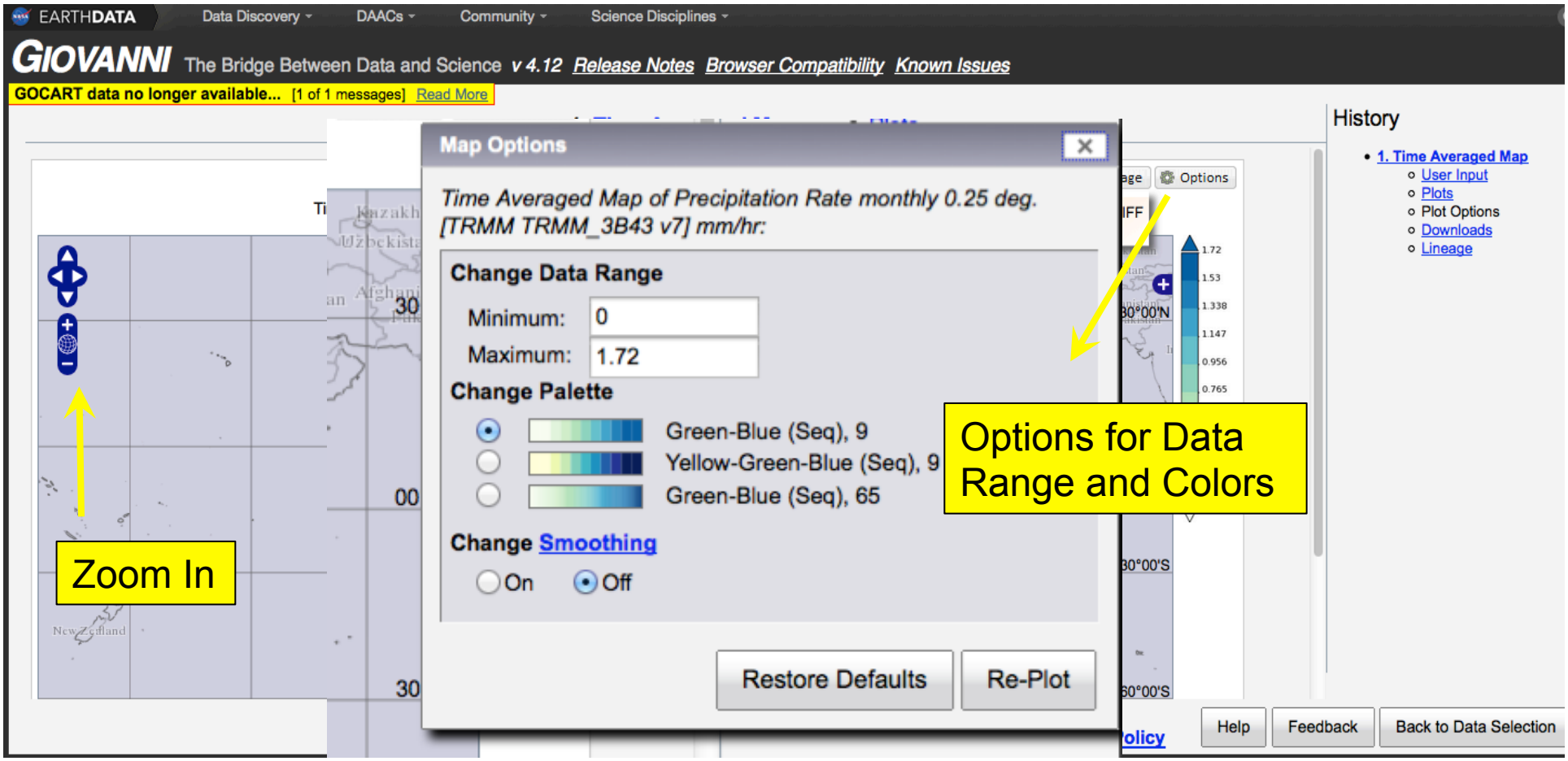
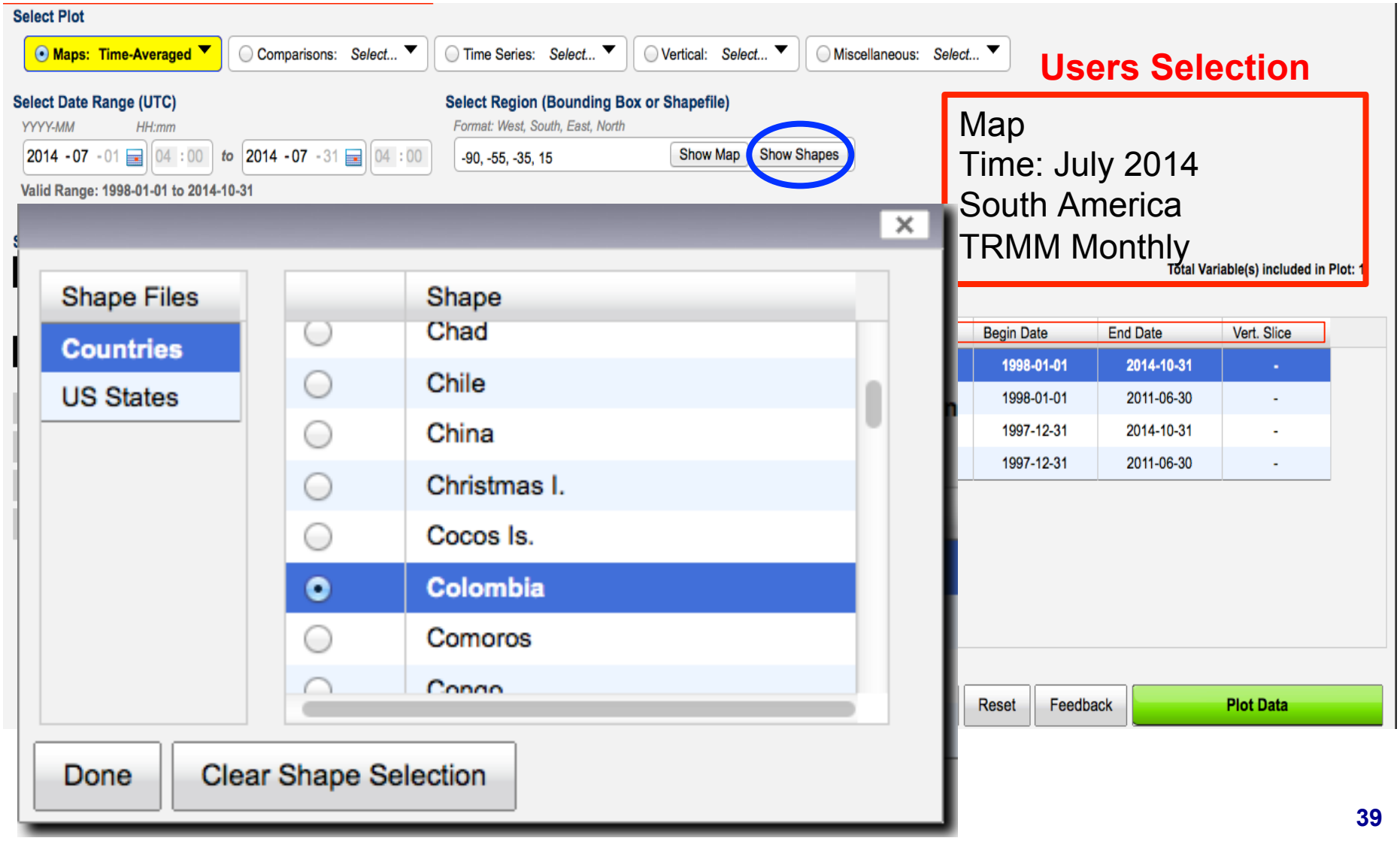


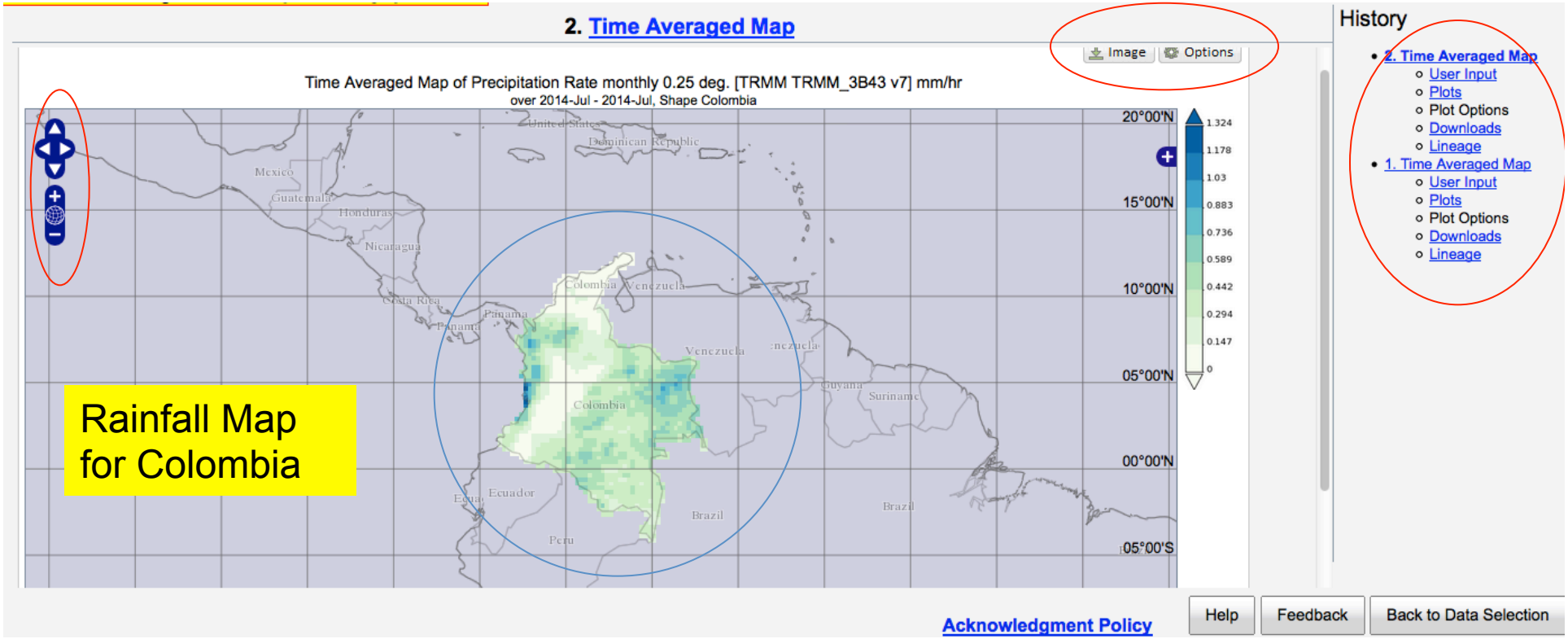
User-Selected Map from Giovanni

Giovanni

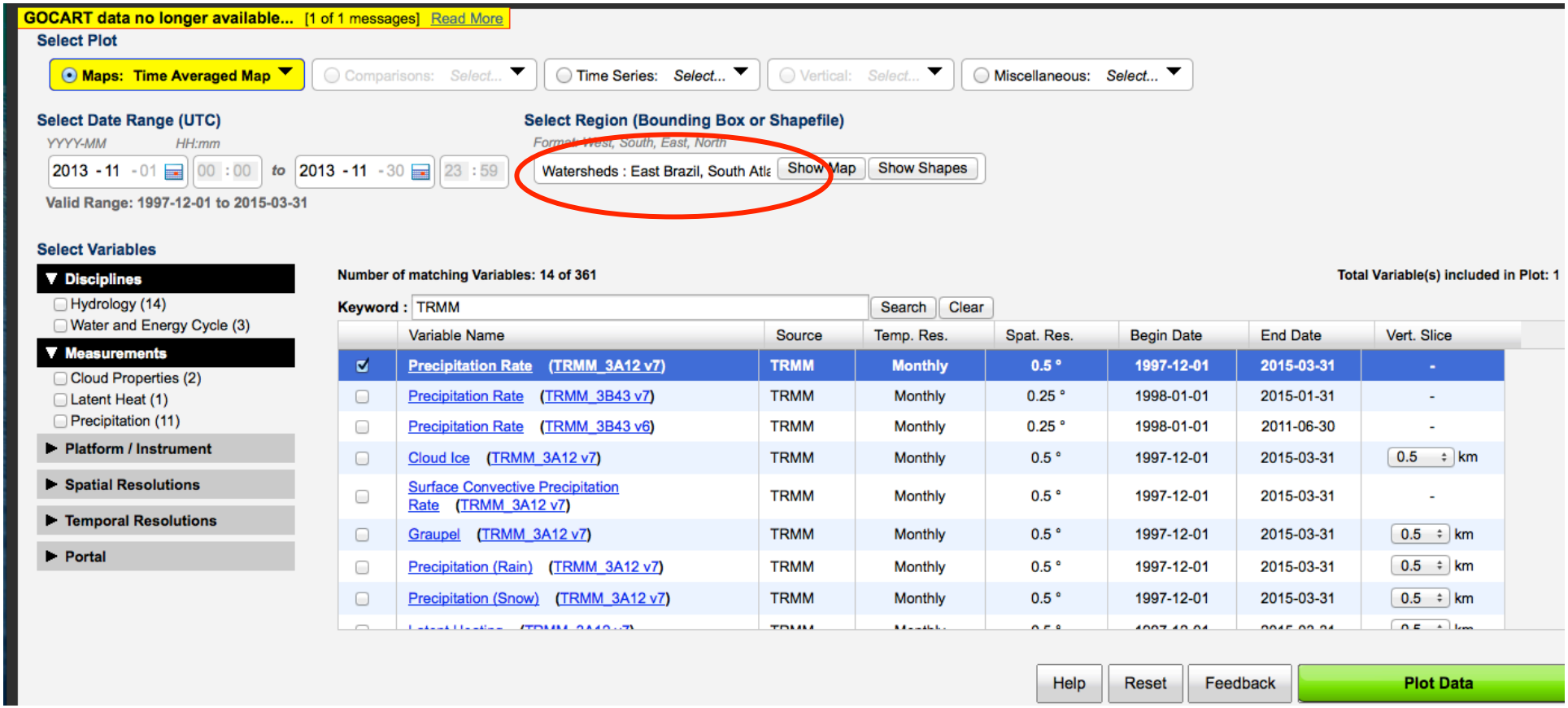
http://giovanni.gsfc.nasa.gov/giovanni/



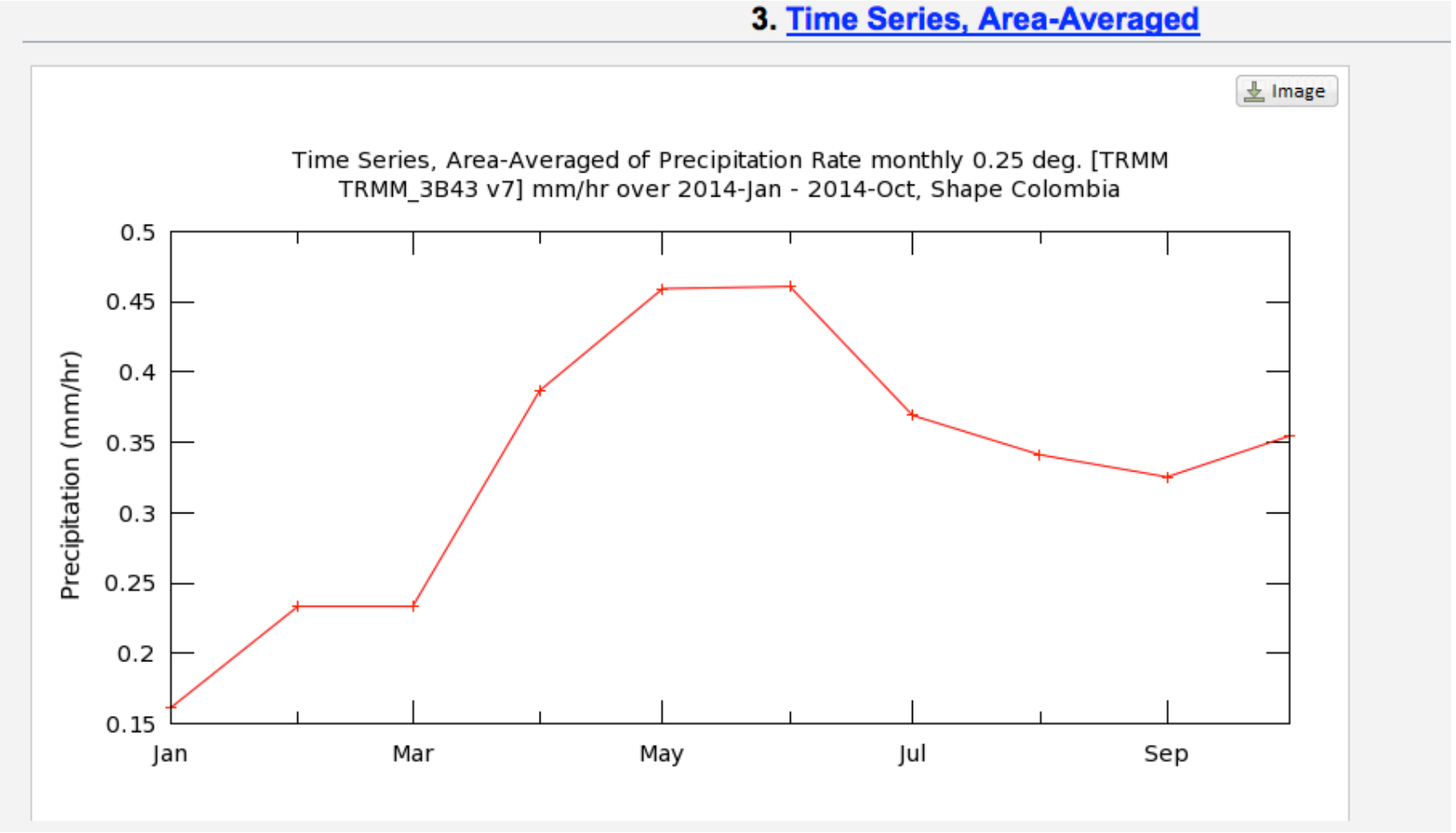
Map for User-Selected Shapefile



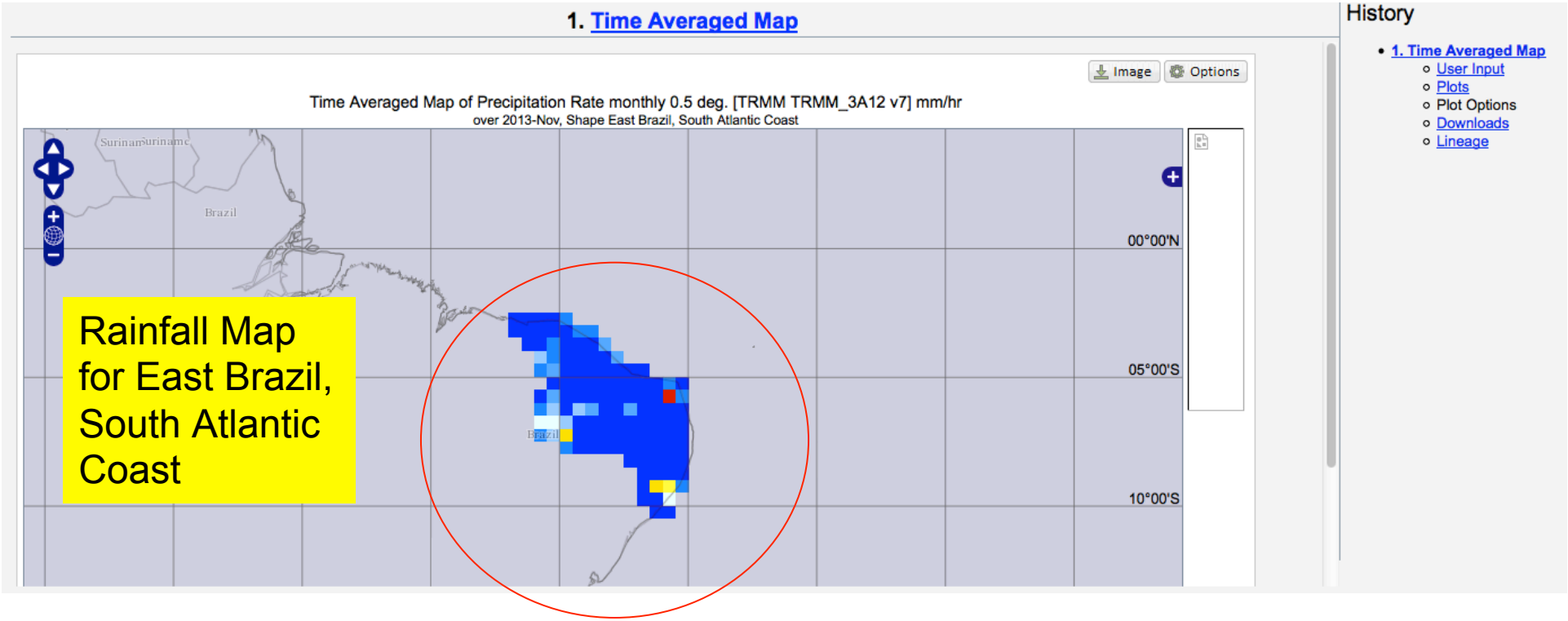
Map for User-Selected Watershed



Area-averaged Time Series Plot



Map for User-Selected Watershed



Next :

Hands-on Activity to access and visualize rainfall using Giovanni